Hurricane Imaging Radiometer (HIRAD) Wind Speed and Rain Rate Retrievals during the 2010 GRIP Flight Experiment

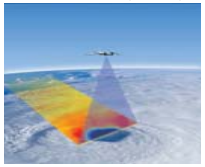
Saleem Sahawneh[1], Spencer Farrar[1], James Johnson[1], Linwood Jones[1], Tim Miller[2], Jason B. Roberts[2], Sayak K. Biswas[2] and Daniel Cecil[2]

1.Central Florida Remote Sensing Lab, Department of EECS, University of Central Florida

2.NASA/MSFC, Earth Science Office, Huntsville, AL

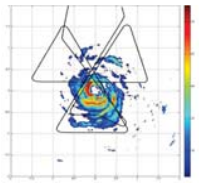
HIRAD Concept

- HIRAD measures surface emissivity and path average rain intensity over a wide swath.
 - Near-instantaneous mapping of entire inner-core hurricane surface wind field and rain structure.
 - Measurement swath ~ 3 × Altitude
 - IFOV ~ 2 Km @ nadir & 5 Km @ EOS
 - Wind speed ~10 – 85 m/s
 - Rain rate ~ 5 – 100 mm/hr
- 4-Freq C-band Radiometer
 - 4, 5, 6 & 6.6 GHz @ H-pol
- One-dimensional Synthetic Thinned Aperture Array Radiometer
- 37 × 16 element stacked patch array antenna.

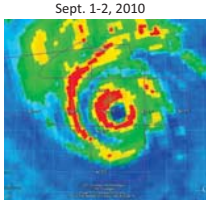


NASA GRIP Field Campaign 2010: Aircraft Flight Lines

Hurricane Karl
Sept. 16, 2010



Hurricane Earl
Sept. 1-2, 2010



Geophysical Retrieval Methods

- Near Real Time "Quick-look" Algo.
 - Single frequency empirical algorithm
 - 5 GHz linear for Wind Speed
 - 6.6 GHz second order for Rain Rate
- Multi-frequency MLE Algorithm
 - 4, 5 & 6.6 GHz for WS and RR
 - Radiative Transfer Theory based
 - Max. Likelihood Estimate of WS and RR
 - Comparing Observed Tb to Modeled Tb
 - Minimizing squared differences over all frequencies

Hurricane Earl Retrievals

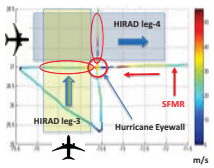
- Quick-look retrievals,
 - Good eyewall structure.
 - Good agreement with SFMR.
 - Rain band south of storm center agrees with WP3D.
 - Single frequency WS susceptible to rain.
- MLE retrievals,
 - Good eyewall structure.
 - Good Max. WS and RR agreement with SFMR.
 - Relatively noisy due to 6.6 GHz signal.

Hurricane Karl Retrievals

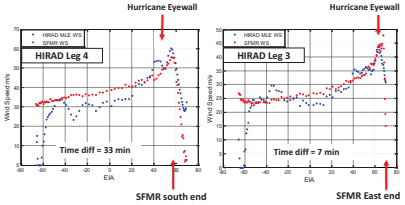
- Quick-look retrievals,
 - Same algorithm as with Earl.
 - Eyewall structure well defined.
 - Max. wind speed in agreement with SFMR.
- MLE Retrievals
 - Two HIRAD passes map entire inner-core hurricane surface wind and rain structure.
 - Good Max. WS and RR agreement with SFMR.
 - T_b calibrations need improvement.

Hurricane Earl

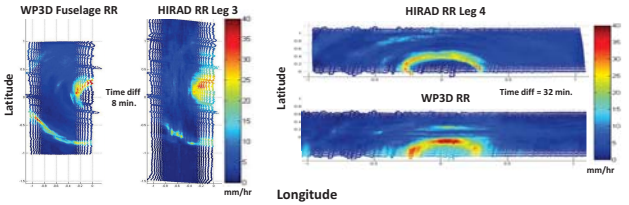
SFMR Simultaneous Crossing of HIRAD Swath (Leg-4: West to East 27.7° Latitude)



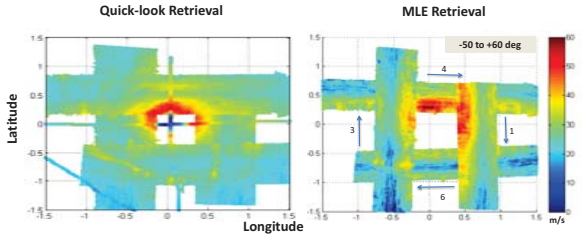
Comparison between HIRAD MLE and SFMR WS



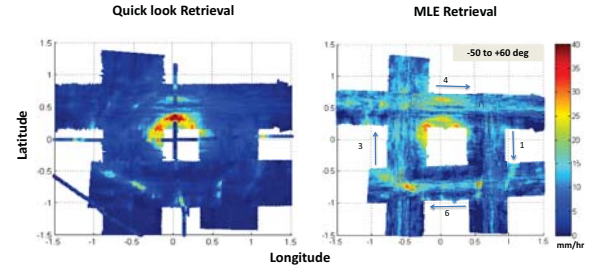
Comparison of HIRAD Quick-look to WP3D RR (HIRAD legs 3 & 4)



Wind Speed Composite Image (MLE 4,5 & 6.6 GHz freq., Legs 1,3,4 and 6)



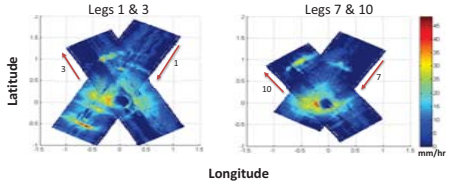
Rain Rate Composite Image(MLE 4,5 & 6.6 GHz freq., Legs 1,3,4 and 6)



Hurricane Karl

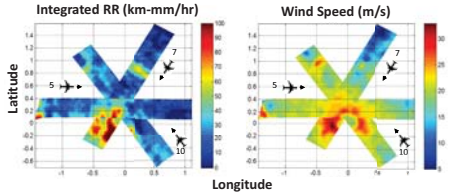
Rain Rate Composite

2 Frequency Retrievals(4 & 5 GHz)



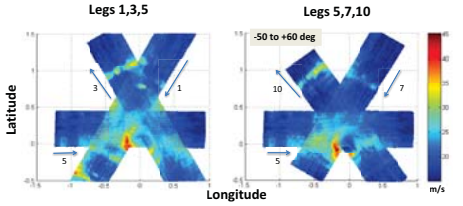
Retrieved wind speed and Integrated rain rate using cross track smoothing

Wind speed was adjusted to match H-winds



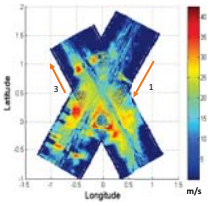
Wind Speed Composite image (Quick-look)

5 GHz frequency



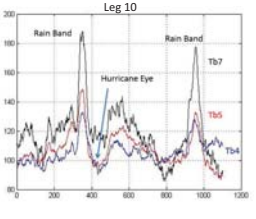
Wind Speed Composite

(4, 5 & 6.6 GHz, -50 to +60 deg.) legs 1 & 3



Current work

Time series of normalized TB @ EIA = 40



NASA Hurricane and Severe Storm Sentinel (HS3) Flight Program

Hurricane seasons 2012 – 2014

- Mission uses a two-Global Hawk UAV configuration:
 - Over the storm & Environment around the storm
 - Over-storm vehicle includes HIRAD, HAMSR and HIWRAP
 - Over-storm vehicle was not ready for 2012 season. One flight
 - 2013 flights September 3,15 and 25 during slow hurricane season.

HIRAD installation on Global Hawk

- During HS3 mission, HIRAD was installed on one of NASA's Global Hawk unmanned aircraft (AV-1)
- Global Hawks have flight durations ~24 hours and fly over hurricanes at altitudes ~ 18 km
- Operated by pilots in ground control stations at Wallops Island, Va. And Dryden Flight Research Center at Edwards Air Force Base, Ca



Conclusion

- The HIRAD concept, with its broad swath measurement capability, offers the potential for significant improvement over the current SFMR
 - Using high-flying, long duration, unmanned aircraft such as the Global Hawk, real-time tropical cyclone surveillance can be possible
- HIRAD has demonstrated the ability to produce a 2D Wind Speed and Rain Rate image in a single pass
 - Swath width is 2x to 3x the aircraft altitude
- Under the HS3 program, hardware improvements have been implemented that improve the radiometric calibration accuracy and stability
 - Future HIRAD retrievals will improve with better calibrated Tb's
 - Anticipate HS3 2014 Hurricane flights
- The HIRAD has the potential for space borne application